22 January 1971

Materiel Test Procedure 2-4-003
Tropic Test Center

US ARMY TEST AND EVALUATION COMMAND
COMMON TROPIC ENVIRONMENTAL TEST PROCEDURE

WHEELED, TRACKED AND GENERAL PURPOSE VEHICLES

1. OBJECTIVE

This document provides test methodology and testing techniques for determining the capability of wheeled, tracked and general purpose vehicles to withstand exposure to, and function effectively within, tropic environments. A principal purpose is to compare data obtained before and after dynamic (terrain transit) and static (storage) environmental tests.

2. BACKGROUND

Army worldwide operations creates a need for developing and testing new equipment. This creates a need for determining whether wheeled, tracked and general purpose vehicles and accessories (hereinafter called test items) will meet specified performance requirements when they are exposed to natural wet-warm or wet-hot tropic environment conditions. Testing under these conditions is generally not conducted until data from simulated environmental tests provides reasonable assurance that the test item will function satisfactorily when subjected to such tropic environment conditions.

See Appendix A for details regarding the following:

a. Environmental characteristics of areas which are available for testing.

b. The conditions encountered, and the expedients which were used, during previous off-road tests of towed, wheeled, and tracked vehicles in the Panama Canal Zone

c. Major Problems associated with tropic areas.

d. Description of fungus-inert and fungus-susceptible materials.

e. Corrosion-resistant properties of metals.

f. Major environmental effects caused by exposure to the Panama Canal Zone climate.

3. REQUIRED EQUIPMENT

NOTE: Unless otherwise specified, the accuracy of all indicating and recording devices shall be at least 10 times greater than the required accuracy. These devices shall be calibrated using reference, or interim, standards whose calibration is certified as being traceable to the National Bureau of Standards, has been derived from accepted values of natural physical constants, or has been derived by the ratio type of self-calibration techniques. Calibration system requirements shall conform to those specified in MIL-C-45662.

One or more of the following items and/or facilities may be required to obtain data during the various evaluations:

a. Tape measure, (steel) 0 to 60.9 meters (200 feet).

b. Still and motion picture cameras, film (black-and-white, and color), floodlights, flashbulbs, electronic flash.

c. Cargo movement restraining devices, such as straps, nets, tie-down devices, pallets, tie-bars, cushioning materials, blocks, braces, lashing material and dunnage.

d. Crane, forklift and wrecker.

e. Platform-type weighing scales, 0 to 120,000 pounds.

f. Fuels and lubricants as specified in the appropriate technical manual.

g. On Vehicle Equipment Material (OEM) and special tools as specified in the equipment manual.

h. Stopwatch.

i. Suitable fording and deep water courses not less than 152.4 meters (500 feet) long.

j. Suitable lengths of steel cable or chain for vehicle towing or recovery purposes.

k. Simulated or actual payload.

l. The following cross-country test course topographies, each starting at and terminating at an access road. Gullies not suitable for test item traversal shall be bypassed. The total course length is contingent upon the type of equipment being tested. If conditions permit, each test course shall terminate at the starting point. When transiting a hilly region, the course shall contain straight up-and-down hill, and curved side hill sections. The course shall make an angle of less than 90 degrees to the gully or stream it is crossing, and it shall be curved so as to traverse the gully or stream at two nearby points. The purpose of this requirement is to insure that the vehicle will "side-hill" down a shallow slope and up a steep slope during one crossing, and "side-hill" down a steep slope and up a shallow slope during the other crossing.

1) Cleared terrain test course topographies.

NOTE: These courses shall be cleared of trees, underbrush, and vines to the extent necessary to duplicate the cleared path expected to be encountered during tactical operations. The path width shall be sufficient to permit the test item, and a reference item of a similar type, when used, to be driven on a parallel course.

a) A hilly region in an early second-growth forest, avoiding steams and gullies. Course shall include side slopes.
b) A relatively level early second-growth forest area having several gullies or shallow streams, each of which has two crossing points located on a curved course.
c) A relatively level early second-growth forest area avoiding gullies and shallow streams and containing a river which has two crossing points located on a curved course.
d) An upland area of steep grassy slopes substantially devoid of trees. Course shall include side slopes.
e) Mature closed canopy "evergreen" tropic lowland forest with little or no undergrowth.
f) Mangrove swamp.

2) Uncleared terrain test course topographies.

NOTE: When the test course is covered with thick vegetation, it shall be first traversed by experienced personnel to avoid the danger of having the test item traverse a hazard which it was not designed to negotiate. The chosen route shall be indicated by fastening two lengths of fungus-proofed white engineering tape at shoulder height on trees or bushes. These lengths shall be spaced a sufficient distance apart to permit the test item, and a reference item, when used, to be transported side by side on a parallel course. The route shall not have been previously traversed by a motor vehicle.

a) Tropic marsh containing touch, thick reeds forming a solid mass of vegetation.
b) A relatively level second-growth forest with dense undergrowth, but with no gullies, streams or rivers to cross.
c) Mangrove swamp.

m. Recovery vehicle.

n. Exposed, secure, test item parking area, with no roof shelter or flooring.

o. Portable radio communications equipment having a minimum range of 2.41 kilometers (1-1/2 miles). (Use horizontal polarization when the antenna will be located near dense forests. See FM 24-18, section 52.)

p. Boat with motor, life jackets, marking buoys, and towlines for amphibious vehicles.

q. Stream velocity meter.

r. Soils testing set.

s. Abney hand level for measuring slopes.

t. Microbiological test equipment.

u. Surveying transit.

v. Base camp facilities for personnel, supplies, repair parts and maintenance.

w. Secure general-purpose warehouse, shed or open storage space, as specified, for long-term environmental storage exposure (surveillance) test.

x. Smooth, level secondary or gravel roadway suitable for performing a vehicle break-in operation.

y. Fungus-proofed white engineering tape (as required).

z. Sound vibration and analyzing equipment.

aa. Vision testing apparatus.

ab. Meteorological equipment for measuring and recording temperature, relative humidity, solar radiation, precipitation and wind.

ac. Strength measuring apparatus (strain gauges, transducers).

ad. Questionnaires and checklists.

ae. Equipment performance report forms.

af. Jungle field uniforms and equipment.

ag. Reference or comparison items.

4. <u>REFERENCES</u>

A. AR 70-10 Research and Development: Test and Evaluation During Research and Development.

B. AR 70-38 Research and Development: Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions.

C. AR 385-10 Army Safety Program.

D. AR 385-16 Safety of Systems, Associated Subsystems and Equipment.

E. AR 740-12 Covered and Open Storage for Supplies.
F. AR 750-1 Maintenance of Supplies and Equipment: Maintenance Concepts.
G. AR 750-15 Maintenance of Supplies and Equipment.
H. USAMC Regulation 385-12 Verification of Safety of Materiel from Development Through Testing and Supply Disposition.
I. USAMC Regulation 385-224 Safety Manual.
J. USAMC Pamphlet 702-3 Quality Assurance Reliability Handbook.
K. USAMC Pamphlet 706-134 Engineering Design Handbook: Maintainability Guide for Design.
L. USATECOM Regulation 70-23 Research and Development of Materiel: Equipment Performance Reports (EPRs).
M. USATECOM Regulation 385-6 Verification of Safety of Materiel During Testing.
N. USATECOM Regulation 700-1 Quality Assurance: Value Engineering.
O. USATECOM Regulation 750-15 Maintenance Portion of Service Test.
P. USAGETA Document Human Factors Evaluation Data for General Equipment (HEDGE) Guidebook Supplement.
Q. MIL-STD-129 Marking for Shipment and Storage.
R. MIL-STD-642 Identification Marking of Combat and Tactical Transport Vehicles.
S. MIL-STD-794 Parts and Equipment, Procedures for Packaging and Packing of.
T. MIL-STD-1472 Human Engineering Design Criteria for Military Systems, Equipment and Facilities.
U. FM 24-18 Field Radio Techniques.
V. FM 31-30 Jungle Training and Operations.
W. TM 743-200 Storage and Materials Handling.
X. USATTC Semiannual Reports beginning Oct., 1966 Environmental Data Base for Regional Studies in the Humid Tropics.
Y. Thompson, W.A. The Relative Size of the Environmental Effect on One Variety of Military Equipment, Report No. 5, Department of Statistics and Statistical Laboratory, Virginia Polytechnic Institute, 1954.
Z. Wilson, Nutall, Raimond Engineers, Inc., Contract Report No. 113-2 Oct. 1964. An Exploratory Study of the Effects of Terrain Surface Obstacles on Vehicle Performance.

5. SCOPE

5.1 SUMMARY

This Materiel Test Procedure describes the following tests

To be conducted on wheeled, tracked and general surface vehicles and their accessories.

5.1.1 Engineering, Integrated Engineering and Service, Tests.

a. Preparation for Test - A determination of the condition of the test item upon its arrival and other preparatory procedures and evaluations to be completed prior to the start of operational testing. These will include:

1) Initial inspection.

a) Condition and marking of all packages and packing, and their adequacy for overseas shipment.
b) Test item physical characteristics (dimensions, cubage, and weight), physical condition, marking, labeling, protective coatings, corrosion and microbiological growths, tie-down and lifting points, and safety features.
c) Missing parts and/or literature.

2) Test Personnel training and familiarization.
3) Initial operation of the test item, to evaluate its operability in its as-received condition and its safety features.

b. Operational Test - An evaluation to determine the capability of the test item to perform its intended mission when utilized by service personnel.

c. Durability - An evaluation to determine the test item's capability to operate for the required period of time, or a given number of miles with a minimum of downtime.

d. Maintainability - An evaluation to determine the average maintenance manhours per test item operating hours.

e. Availability - An evaluation to determine the inherent and the achieved availability of the test item.

f. Reliability - An evaluation to determine the reliability of the test item at a predetermined confidence level.

g. Safety - An evaluation to determine the safety characteristics and possible hazards to which the test item is exposed.

h. Human Factors - An evaluation to determine those design and performance characteristics effecting the test item user which

are peculiar to the tropic environment.

i. Value Analysis - An evaluation directed at analyzing the primary function and features of the test item for the purpose of cost reduction without compromising performance reliability, quality, maintainability or safety.

5.1.2 Surveillance Test

An evaluation to determine the ability of the test item to withstand long-term storage in the specified environment.

5.1.3 Battlefield Day (Tanks and Tracked Vehicles Which Accompany Tanks Only)

An evaluation to determine the length of time (In Hours) that the vehicle can operate continuously on a full tank of fuel over indicated simulated battlefield terrain.

5.2 LIMITATIONS

This MTP is intended to be used as a basic guide in preparing actual test plans for the subject equipment. Specific criteria and test procedures must be determined only after careful appraisal of pertinent QMRs, SDRs, TCs, and any other applicable documents.

These procedures are limited to tests on operating system components which require exposure to those combinations of weather and terrain conditions, described in Appendix A, which are available in the Panama Canal Zone or in the Rio Hato Training Area. It is assumed that these components have been subjected to, and successfully passed, those tests which are unaffected by ambient weather or terrain conditions, or which can be appropriately made in a temperate climate.

6. PROCEDURES

6.1 PREPARATION FOR TEST

6.1.1 Initial Inspection

a. Inspect and record the condition and identification marking of all packages and packing and their conformance to MIL-STD-794 for overseas shipment for Level A or Level B, as applicable.

b. Weigh and measure the individual package(s) of each packaged test item component, or a sample package, if identical components are contained in several packages.

Record the following for each package measured:

1) Contents.
2) Weight.
3) Length, width and height.
4) Cubage.

c. After unpacking, perform and record the following for each component:

1) Remove all preservative coatings.
2) Inspect the physical condition, protective finishes and safety features provided, including appropriate safety markings on explosive material containers, and inspection approval stampings on pressure vessels.
3) Inspect vehicle markings for conformance with MIL-STD-642.
4) Note the presence of instruction plates and other markings for their adequacy and accuracy as required by the draft technical manuals.
5) Measure the overall dimensions, and weight, and calculate the cubage.
6) Note the presence of center of gravity markings when required.
7) Inspect for, and take color photographs of, all surfaces displaying corrosion or microbiological growths.
8) Inspect for any missing parts and/or literature.
9) For all assemblies, subassemblies and accessories:

   a) Nomenclature.
   b) How assembled (properly or improperly).
   c) How secured.

10) Inspect for special tools and/or facilities required for repairs and adjustments.
11) For towed components, measure:

    a) Rear pintle height, in centimeters and inches.
    b) Minimum ground clearance in centimeters and inches.
    c) Angle of approach, in degrees.
    d) Angle of departure, in degrees.

12) Note the identification number and nomenclature of all special purpose kits.
13) Inspect for bent, loose, broken or missing parts.
14) Inspect for malfunctions and repairs on fasteners such as latches, locks and catches.
15) Note the functional performance of all rotating or

sliding mechanically-moving parts such as hand-operating positioning wheels or levers.

16) Note the physical condition of fragile parts such as indicating meters.
17) Note the braking action on all brake-equipped vehicles.
18) Inspect for leakage on gas or liquid storage containers.
19) Inspect the internal pressure and physical condition of all vehicle tires.

6.1.2 Test and Support Personnel Instructions

a. Instruct personnel as follows:

TABLE I
Personnel Instructions

Personnel	To be instructed in
All	a. The purpose of the test. b. The characteristics of the test item. c. The characteristics of the reference item, if any. d. The kind of data to be obtained. e. The health precautions to be observed in the terrain being traversed. f. The terrain to be traversed.
Test and reference item operators	a. The test item (and reference item, when used) operating characteristics and limitations. b. The expected test item performance. c. The safety precautions to be observed. d. The kind and extent of all maintenance actions to be taken under all specified environmental conditions.

	e. All operating procedures to be followed under all environmental and terrain conditions. f. The procedures to be followed when filling out checklists and questionnaires, and their purpose. g. Technical Manuals to be utilized.
Test evaluators	a. The purpose and use of all checklists and questionnaires, and the methods to be used in their evaluation. b. The mathematical models to be used in evaluating the test data, and the calculations to be made.
Topographical analysis support	a. Physical terrain features to be measured, including water velocity and terrain slopes. b. Vegetation features to be noted and described.
Maintenance support	a. The scheduled maintenance requirements to be met. b. The procedures, equipment and material to be used to make emergency repairs and unscheduled maintenance. c. The kind of recovery vehicle to be used. d. The recovery procedures to be used. e. The maintenance records to be written.
Meteorological support	a. The terrain areas which will be used. b. The calendar dates of all tests. c. The readings to be taken.

Soil analysis support	a.	The nature and location of major terrain soils to be traversed.
	b.	The kind and extent of all soil analysis to be performed.
Storage and surveillance test	a.	Storage, handling, layout, spacing, pest control, fire protection, security, and inspection procedures to be followed.
	b.	Required organizational maintenance to be performed, including cleaning, and microbiological inspection.
	c.	The calendar dates of all inspections.

b. Record the amount of time, and type of training or familiarization required by each member of the various test teams, and indicate any exceptional difficulties encountered.

c. Evaluate and record the adequacy of all draft technical manuals and safety instructions used by the test personnel. This evaluation shall continue throughout the course of the test.

6.1.3 Preliminary Operations

NOTES: 1. Verify that a safety release statement has been received from USATECOM before making any tests.

2. All initial inspections and operations shall be conducted as specified in the applicable draft technical manuals.

3. Observe all specified safety requirements at all times.

Perform and record the following as applicable.

a. Fully fuel, clean and lubricate the test item, as required.

b. Measure and record the physical dimensions of parts which can be expected to have a high wear rate.

c. Perform a functional test on all fire extinguisher

systems. This shall include weighing cylinders before and after discharge, and measuring the effort required by the operator to release the extinguishing element.

d. Inspect the condition of all amphibious vehicle water transit equipment, such as the breathing, exhaust, ignition, pontoons, engine-cooling fan shut-off, and water propulsion devices, as applicable.

e. Operate all movable parts by hand and verify that all final adjustments have been made to insure proper operation.

f. Drive or tow the vehicle the specified distance forward and backward along a paved, substantially level road, and note the adequacy of the safety features provided.

g. If the vehicle has not been previously used, perform the specified break-in test on it, and note the mileage reading obtained at the end of the test, in kilometers and miles.

h. Visually examine, and take color photographs of, all accessible surfaces displaying corrosion or fungus growth, and conduct suitable physical and microbiological examinations of these conditions. Note and record all materials which are considered to be vulnerable to corrosion or microbiological attack.

i. Verify that all adjustments have been made to insure proper operation.

j. Record the results of all inspections for corrosion or fungus growth.

6.1.4 Statistical Plan

NOTE: In this plan, one transit of a test course will be considered to consist of one pass in each direction, with the transit terminating at the starting point.

Perform and record the following:

a. To obtain the maximum amount of useful information, use the same personnel in both the wet season and in the dry season.

b. Verify that, at the beginning of each transit, the test item has been restored to its initial pre-trial condition with respect to all of those features which are considered to be important from a reliability standpoint.

c. Assign each test item to the particular individuals or crews who will be operating it.

d. Select a minimum of two crews or drivers, as applicable, from available, suitably-trained troops.

e. Using a "block design" procedure such as that described in Appendix B, determine which of these crews or drivers will be used in the traverse of each of the applicable cleared and uncleared test courses described in item (e) under 3, "REQUIRED EQUIPMENT", and describe the test courses to be traversed by them.

f. Describe, in detail, what constitutes a failure in each test performed.

g. When a reference item is to be used for comparison purposes, follow the procedures described under steps (d) and (e) above for the reference item personnel.

h. The total number of traverses to be made, over each of the specified test courses shall be that number necessary to provide accurate data

where the total number of traverses = N x T

and N = number of test items

and T = number of traverses made by each vehicle.

6.1.5 Mission Scenario

Prepare and record a mission scenario similar to the mission requirements scenario, and include the following:

a. Details of each single and multiple course traverse test.

b. A sketch map, or a photomap, as needed, illustrating the sequence of single courses described in item (n) under 3, "REQUIRED EQUIPMENT", to be traversed in each direction to constitute a single multiple course traverse. The length of each of these single courses shall not be less than 6.44 kilometers (4 miles), unless otherwise specified in the test plan.

6.2 TEST CONDUCT

NOTES: 1. Verify that a safety release statement has been received from USATECOM before making any tests.

2. Observe all specified safety requirements at all times.

6.2.1 General Requirements

a. Conduct the test under existing weather conditions, and record all weather conditions encountered.

b. Unless otherwise specified, avoid the ruts made by a previous vehicle.

c. When a reference item is being used, take it over a course parallel to that taken by the test item, but trail it behind the test item a sufficient distance to avoid the danger of it becoming immobilized by the same terrain feature which has immobilized the test item.

d. Traverse the test course during daytime and night time hours unless safety indicates only daytime testing.

e. Perform grass land testing in the dry and wet seasons.

f. Select each test course to include the terrain and vegetation conditions for which the test item was designed. Unless otherwise specified, each course shall be not less than 6.44 kilometers (4 miles) long.

g. To simplify data analysis, traverse only one of the several applicable terrains at a time, unless otherwise specified.

h. To accomplish a test course transit, make one pass in each direction, terminating at the starting point.

i. When measuring features such as braking distance, slope slippage, soil strength, or average MPH, make at least two, and preferably four, independent measurements and record each measurement, their arithmetic mean, and the percentage accuracy of the measuring device.

6.2.2 Operational Test

6.2.2.1 Initial Inspections

Perform the following on the test item (and the reference vehicle, when used) at the beginning of each test course traverse, and record all data obtained:

a. An operator pre-operational inspection in accordance with the draft technical manual.

b. Note the vehicle mileage in kilometers and miles at the start of the test, and describe the test course to be traversed, including vegetation and topographic features.

c. Fully fuel the test item and lubricate it to the

extent required by the vehicle mileage reading.

d. Inspect the air and oil filters, and the cooling system, and insure that they are in an acceptable clean condition.

e. Clear all debris from the radiator cooling surfaces.

f. When the test path is forested, conduct a nearest neighbor distance transect of tree stems, enumerating diameters breast high. Calculate the estimated permissable speed of the test vehicle operating along the test course using tree size, spacing, and form, as specified in REFERENCE Z.

g. Determine that all on-board accessories are on hand, and are properly stowed.

h. Verify that the air pressure in the tires, and the water level in the cooling system, meet specified requirements.

i. When a simulated cargo load is used, verify that it simulates the weight and center of gravity location of the specified actual load.

j. Perform and record the following during a period of no rain, and just before each traversal of the test course, unless otherwise specified, using a sketch map, or a photomap, of the test course for reference, as needed.

1) Verify that no terrain conditions or obstacles exceed the limits allowable for the test course.
2) Determine the California Bearing Ratio (or core indices) for the test course soils.
3) Measure the stream and river water velocities at the vehicle crossing points, and show the measuring point locations on a map showing the water channel cross-section and water depths.
4) Indicate all vertical and side slopes exceeding 10 percent along the test course.

6.2.2.2 Single Course Traverse - Dry Season

NOTES: 1. Perform these tests during the dry season, which normally starts in January and ends during March.

2. The test item shall be driven over only those test course terrains described under item e, paragraph 3. "REQUIRED EQUIPMENT" for which it was designed.

Perform the following, and record all test results:

a. Drive the vehicle (and its attached trailer, when used) over the test course for the first of the traverses specified under paragraph 6.1.4 above.

b. During this traverse, perform only those operator-type maintenance and repairs which are required to keep the test item moving along the course.

c. Use the particular crew for this traverse as specified under Paragraph 6.1.4.

d. At the end of the traverse, note the following:

1) The total time taken.
2) The time consumed in making the maintenance and repairs described in step b above, and recovery from immobilization.
3) Driver/crew comfort or fatigue.
4) Adequacy of all controls and indicators.
5) The fuel consumption.
6) The ambient temperature, humidity, wind, solar radiation and rainfall encountered.
7) The amount of slope slippage encountered.

e. At each test item immobilization point, perform the following:

1) Describe the location and cause of the immobilization and the means used to either free the test item, or to recover it, as applicable.
2) Take a sample of the soil underlying the vehicle at the immobilization point, for later analysis.
3) Describe the vegetation encountered, and the condition of the surrounding terrain.
4) Describe all damages sustained by the test item, and all repairs made.
5) Measure the time interval required to restore the test item to a usable condition, in case the test course transit is resumed.

f. At the end of the course traverse, note the vehicle mileage and record the following test item features:

1) Maximum speed attained in KMH and MPH.
2) Braking performance.
3) Slope slippage performance.
4) Maneuverability.

5) Stability.
6) Average speed in KMH and MPH.
7) The extent of water shipment during water level.
8) Backing up and steering ability.
9) Stability and protection of cargo.
10) Vegetation impediments.
11) The condition of all stowed items.
12) The adequacy of the test item safety features and the safety instructions.

g. At the end of the course traverse, perform the following:

1) Ask the test item crew (and the reference item crew, when used), to fill out a questionnaire giving their opinion of the performance of their own vehicle and its relative merits or demerits as compared to the other vehicle. See Appendix B for guidance in preparing a suitable questionnaire.
2) Make all repairs, replacements, cleaning and lubricating needed to restore the test item (and the reference vehicle, when used) to the condition it was in at the start of the test course traverse.

h. When the statistical plan described under paragraph 6.1.4 requires more than one traverse of this same test course, repeat steps a through g above until the total number of traverses have been completed.

i. Perform steps a through h above until all of the specified single courses have been traversed. To the greatest extent practicable, insure that the terrain and weather conditions are the same during each traverse.

6.2.2.3 Multiple Course Traverse - Dry Season

After completing the tests described under paragraph 6.2.2.2, perform the tests described in paragraphs 6.2.2.2 a through 6.2.2.2 h, except that the test course shall consist of the several single courses described under paragraph 6.1.5.

6.2.2.4 Environmental Storage

NOTES: 1. Unless otherwise specified, the beginning of this storage test shall be immediately after the Multiple Course Traverse Test described under paragraph 6.2.2.3 has been completed, and it shall last until the peak of the wet season, which normally occurs during the months of October and November.

2. When more than one test item is being stored, the number of samples inspected shall be as shown in paragraph 6.1.1, Table I, unless otherwise specified.

Perform and record the following:

a. Unless otherwise specified, park the test item on the ground, without blocking and without shelter in the specified environment, and in a secure (locked and patrolled) area.

b. Make daily measurements of the weather conditions throughout the storage period.

c. During the storage period, conduct the following tests on the selected samples, unless otherwise specified.

1) Each week, make a general inspection for weather effects and rodent attack. Inspect for rain penetration or collection during the rainy part of the day, whenever possible.
2) Each month, inspect all accessible surfaces and take color photographs of each area showing corrosion or fungus growth.
3) Each three months, after filling the fuel tank full, remove the test item from its parking position and drive it over a relatively level, paved road, forward and backward, not less than 15.2 meters (50 feet).

d. At the end of the storage period, perform and record the following:

1) Remove every test item from storage and visually examine it.
2) Take color photographs of all corrosion and fungus growth areas.
3) Make a microbiological analysis of all materials which display evidence of microbiological attack.
4) Perform all specified operator maintenance and repairs needed.
5) Perform the operational test described in paragraph 6.2.2.2 or paragraph 6.2.2.5 as applicable.
6) Determine to what extent the operational characteristics of the test item have deteriorated during storage.

e. The calendar month, day and hour of the start and finish of the storage period, and of all inspections.

6.2.2.5 Single Course Traverse-Wet Season

Perform the tests described under paragraph 6.2.2.2 during the wet season, and record all test results.

6.2.2.6 Multiple Course Traverse-Wet Season

Perform the tests described under paragraph 6.2.2.3 during the wet season, and record all test results.

6.2.2.7 Durability

During the operational tests described under paragraph 6.2.2 and for all the selected test courses, record the following:

1) Mileage and total operating hours.
2) Speeds attained.
3) Terrain and environmental conditions.
4) Damage to test item or components.
5) Malfunctions of equipment.
6) Maintenance downtime.

6.2.3 Maintainability

During the operational tests described under paragraph 6.2.2, perform and record, in both clock hours and manhours, the following under the applicable headings for each of the test courses traversed.

a. Active scheduled maintenance time.

   1) Describe the procedures and any special tools used.
   2) Record the following:

      a) Inspection start time.
      b) Preparation time.
      c) Fault location time.
      d) Fault correction time.
      e) Part replacement time.
      f) Adjustment and calibration time.
      g) Checkout time.

   3) Add up all of the time intervals involved under 2) and show the total active scheduled time consumed.

b. Active unscheduled maintenance time.

   1) Describe the procedures and any special tools used.
   2) Record the following:

a) Inspection time.
b) Preparation time.
c) Fault location time.
d) Fault correction time.
e) Part replacement time.
f) Adjustment and calibration time.
g) Check-out time.
h) Corrective maintenance deemed necessary as a result of initial technical inspections, except for damage incurred during shipment.
i) Corrective maintenance deemed necessary as a result of operators services and inspections.
j) Deferred maintenance performed during the final technical inspection.

3) Add up all of the time intervals involved under 2 and show the total active unscheduled time consumed.

c. Other Maintenance Times.

1) Describe the procedures and any special tools used.
2) Record the following:

a) Daily operator's services and inspections.
b) Modification and kit installation times.
c) Repair of damage caused by accident or operator/crew error (unless associated with improper design of test item or lack of clarity of instructions in the operator/ maintenance manuals).
d) Supply delay time.
e) Administrative delay time.
f) Technical engineering investigations or inspections related to analysis of cause of failure or detection of suspected incipient failures.
g) Initial and final technical inspections.

d. For all maintenance:

1) Evaluate the adequacy of the draft technical manual.
2) Evaluate the adequacy of the OEM tools and repair parts.
3) Evaluate the adequacy of the safety instructions.

6.2.4 Reliability

During the operational tests described under paragraph ?.2.2, record the following for each of the test courses traversed, under the applicable headings:

a. Chargeable test item failures.

NOTES: 1. Consider simultaneous related malfunctions as one failure.

2. Do not consider as failures those malfunctions which would not affect mission performance.

1) Describe and record each malfunction which the operator/crew cannot remedy by an adjustment, repair or replacement action using the controls, OEM tools and OEM parts within the time established, and which causes, or may cause:

a) Failure to commence operation.
b) Cessation of operation.
c) Significant degradation of performance capability of the system/subsystem.
d) Serious damage to system/subsystem by continued operation.
e) Serious personnel hazards.

2) Describe and record the following:

a) Test item component (<u>not</u> system) failures which cause accidents.
b) Incipient failures corrected by direct or general support maintenance.

3) Add the number of failures recorded under 1 and 2 above and designate the sum as the total number of chargeable test item failures.
4) Record the total operating time.
5) Divide item 1 above by item 3 above and designate the quotient as the mean time between failures (MTBF).

b. Non-chargeable test item failures.

Describe and record the following:

1) Test item failures which result from not following the prescribed operational and/or maintenance procedures dictated by the applicable technical

manual, or which can be directly attributed to improper replacement of components or assemblies.

2) Test item failures which result from accidents.
3) Incipient failures detected and corrected during scheduled preventive maintenance inspections or services at the organizational level.

NOTE: Normal organizational maintenance performed during the scheduled preventive maintenance service and inspections should be sufficient to give reasonable assurance of trouble-free operation until the next scheduled service. Therefore, no active maintenance, other than operator/crew authorized maintenance, will be performed (if such maintenance affects the system performance) between the scheduled services and inspections unless such maintenance is accomplished to correct a chargeable system failure. Examples of permissible maintenance between scheduled services and inspections are ---

a) Replacement of bulbs.
b) Replacement of fuses, such as headlight or horn fuses.
c) Replacement of tires damaged by foreign objects or road hazards.
d) Tightening of fasteners.
e) Minor body repair or painting which cannot be deferred.
f) Normally daily services, including pre-, post-, and during operation checks and services called for in the operator's/maintenance manual.

6.2.5 Availability (See 6.4.3)

6.2.5.1 Inherent Availability (A_i)

Record the following for each test course traverse made:

a. The total number of manhours of active unscheduled maintenance time, as shown under paragraph 6.2.3 b 3).

b. The total number of chargeable test item failures, as shown under paragraph 6.2.4 a.

c. Divide item a) by item b), and designate the resultant quotient as the mean time to repair (MTTR).

6.2.5.2 Achieved Availability (A_a)

Record the following separately for each test course traverse made:

a. The total number of manhours of active unscheduled maintenance time as shown under paragraph 6.2.3 b 3) plus the total manhours of active scheduled maintenance time as shown under paragraph 6.2.3 a 3). Designate the sum of these times as the total active maintenance time.

b. The total operating time in hours.

c. Divide item b) by item a), and designate the resultant quotient as the mean time between maintenance (MTBM).

d. The total number of active scheduled maintenance actions plus the total number of active unscheduled maintenance actions.

e. Divide item a) by item d), and designate the resultant quotient as the mean active maintenance downtime ($\bar{M}$).

6.2.6 Safety

a. Do not begin testing until a safety release is received from high headquarters.

b. Observe the proper safety precautions during testing, and record any conditions that might present a safety hazard, the cause of the hazard, and the steps which were taken to alleviate the hazard.

c. Observe and record all of the precautions specified in the following documents:

1) The test item maintenance test packages.
2) USATECOM Regulation 385-6.
3) FM 31-30.
4) Applicable portions of Appendix B (Questionnaires).
5) Applicable portions of Appendix C (Checklists).

d. After completing all testing, prepare a safety confirmation if the test item was determined safe for use, to be included in the final report.

6.2.7 Human Factors Evaluation

Develop task/item checklists which detect the human factors design considerations for the test item. These checklists will provide for test supervisory personnel comments regarding the degree to which human factors design considerations have been included in the human factors

environmental criterial for the test item. Detailed criteria and human factors considerations for each task may be derived from USAGETA document "Human Factors Evaluation Data for General Equipment (HEDGE) Guidebook Supplement". Consult Appendix C and MIL-STD-1472 for guidance in preparing a suitable checklist.

6.2.8 Value Analysis

a. During the conduct of all tests, test personnel shall evaluate the test item from a value versus cost standpoint. Record all pertinent comments concerning features or components which can be eliminated or modified to accomplish cost reduction without impairment of performance, reliability, quality, maintainability, or safety. The applicable portions of USATECOM Regulation 700-1 shall be used for this evaluation.

b. Consideration shall be given to the topics listed below. Record appropriate comments for each topic.

1) Mission Capacity. The test item should be capable of accomplishing the specified task with only a reasonable margin of excess capability. Excess capacity and unused capability normally results in unnecessary bulk, excessive weight and unwarranted costs.
2) Simplicity. Unnecessarily complex components and systems, redundancy, and the use of unneeded parts will increase costs and maintenance efforts.
3) State of the Art. In many instances the use of recently developed, currently available, components and automated features will result in an overall product improvement and cost savings.
4) Standardization. The use of identical parts and parts currently in the military system will reduce the overall logistics burden.
5) Materials and Methods of Construction. Polished surfaces, overdone finishes, and the use of expensive materials will result in unnecessary costs if used inappropriately.
6) Clearances. Inadequate clearances will result in difficulties and delays in accomplishing post arrival assembly, routine maintenance, servicing and repair.

6.2.9 Surveillance Test

a. Subject the test item to the initial inspections and operations described in paragraph 6.2.2.1, and correct all defects found.

b. Prepare the test item for long-term storage as described in the draft technical manuals.

c. Store the test item in the specified environment, using the applicable procedures described in TM 743-200. Wheeled vehicles shall be blocked off the ground, so that rubber tires are off the ground. When storing such vehicles for a long term, or when they are loaded, it may be desirable to place blocks between the axle and the frame to relieve the pressure on the springs. Tracked vehicles shall be stored on long dunnage. Shipping containers shall be loaded and sealed as specified in the draft technical manuals.

d. When more than one test item is to be stored, divide the number of test items into two or more sample groups up to a maximum of four groups, and identify the samples in each group.

e. Divide the total storage period into the same number of time periods, each of the same length, as the number of sample groups used.

f. At the end of each time period, withdraw one sample group from storage and perform the following on each test item:

1) Visually examine it, and take color photographs of all corrosion and fungus growth areas.
2) Make a microbiological analysis of all materials which display evidence of microbiological attack.
3) Perform all specified operator maintenance and repairs needed.
4) Perform the operational test described in paragraph 6.2.2.2 or paragraph 6.2.2.5, as applicable.
5) Determine to what extent the operating characteristics of the test item have deteriorated during storage.

6.2.10 Battlefield Day (Tanks and Tracked Vehicles Which Accompany Tanks Only)

Obtain data following procedures outlined in fuel and oil consumption (MTP 2-3-513)

6.3 TEST DATA

6.3.1 General Requirements

a. When measuring attributes, which are subject to small deviations, make at least two, and preferably four, different measurements under identical test conditions, and record each measurement, as well as the arithmetic mean of these measurements. Also, record the percentage accuracy of the measuring device used.

b. Indicate the accuracy of the measuring device employed when recording measurements which must be made accurately.

c. When progressive degradation is observed on any part, describe and/or photograph the degradation, and show the "before" and "after" condition together when recording.

d. When applicable, show a soil profile of the test course terrain in the test course performance record.

e. When two or more persons are asked to fill out a questionnaire giving their opinion regarding specified features in a particular test, show the scoring values used, and the scoring results obtained, in tabular form as described in Appendix B (Questionnaires). When an analysis of variance is used to test for the significance of the variation in the scoring results, state the results of this analysis.

6.3.2 <u>Preparation for Test</u>

6.3.2.1 Initial Inspection

Inspect and record the following, as applicable:

a. Identification markings.

1) Name of manufacturer.
2) Other pertinent markings.

b. Condition of all packages and packing, and conformance to MIL-STD-794 for overseas shipment.

c. For each package or sample package, as applicable:

1) Contents.
2) Weight.
3) Length, width and height.
4) Cubage.

d. For each component, after unpacking, as applicable:

1) Physical condition.
2) Preservation coatings.
3) Protective finishes.
4) Safety features and markings.
5) Instruction plates and markings.
6) Conformance of vehicle markings to MIL-STD-642.
7) Overall dimensions, weight and cubage.
8) Center of gravity markings.
9) Color photographs of all surfaces displaying corrosion or microbiological growths.
10) Missing parts, tools and/or literature.
11) The following on all assemblies, subassemblies and accessories:

a) Nomenclature.
b) How assembled and secured.
c) Cleanliness.
d) Adjustments required.
e) Operability.
f) Repairs performed.
g) Functional performance.
h) Physical condition of fragile parts.
i) Mechanical alignments.

12) On towed components:

a) Rear pintle height.
b) Minimum ground clearance.
c) Angles of approach and departure.

13) Identification and nomenclature of all special purpose kits.
14) Braking action on brake-equipped vehicles.
15) Leakage on gas or liquid storage containers.
16) Internal pressure and physical condition of vehicle tires.

6.3.2.2 Test and Support Personnel Instructions

Record the following:

a. Adequacy of the draft technical manuals for:

1) Each test item component.
2) The completely-assembled test item.
3) Each maintenance support component.
4) Each test item performance testing component.
5) All testing and measuring facilities used for meteorological, microbiological, soil and terrain measurements.

b) The following for all test personnel:

1) MOS and skill level.
2) Rank.
3) Unit.
4) Experience.
5) Previous training.

c. Any unusual difficulties.

6.3.2.3 Preliminary Operations

Record the following, as applicable:

a. Physical dimensions of all parts which can be expected to be subjected to unusual wear during terrain traverse.

b. Results of the functional test on all fire extinquisher systems.

c. Condition of all amphibious vehicle water transit equipment.

d. Adequacy of the safety features provided.

e. Break-in mileage.

f. Color photographs of all accessible surfaces displaying corrosion or fungus growth, and the results of the physical and microbiological examinations made.

g. All materials which are considered to be vulnerable to corrosion or microbiological attack.

h. Results of all electronic alignments performed.

i. All adjustments made to insure proper operation.

j. All safety precautions observed.

6.3.2.4 Statistical Plan

Record the following, as applicable:

a. The personnel used in all test course traverses, and the identification number of the test item assigned to each man.

b. The condition of the test item (and the reference item, when used), at the beginning of each transit.

c. The test courses to be used, and their assignments to the test crews, or groups, as applicable.

d. The definition of what constitutes a failure.

e. The total number of traverses made over each test course.

6.3.2.5 Mission Scenario

Record the following, as applicable:

a. The sketch map and/or photomap of all test courses.

b. The length of each test course in miles.

c. The kind of cargo used.

d. All other requirements in the mission requirements scenario.

6.3.3 Test Conduct

6.3.3.1 Operational Test

6.3.3.1.1 Initial Inspections -

Record the following at the beginning of each test course traverse:

a. The vehicle mileage at the start of the test, and the test course to be traversed.

b. The vehicle fueling, lubrication and engine cooling system status.

c. The locations and "vegetative cell diameters" to be encountered along a tree-covered test course.

d. The presence and condition of all on-board accessories and/or cargo.

e. The air pressure in all tires.

f. The condition of the test course.

6.3.3.1.2 Single Course Traverse - Dry Season-

Record the following for each traverse:

a. The calendar month and day.

b. The total time taken.

c. The maintenance, repair and/or recovery operations performed, and the time taken for each operation.

d. Driver/crew comfort or fatigue.

e. Adequacy of all controls and indicators.

f. Fuel consumption.

g. Weather conditions and solar radiation.

h. Amount of slope slippage.

i. Details of all immobilization and recovery operations.

j. Total mileage, maximum speed, braking performance, maneuverability and average speed in MPH.

k. Extent of water shipment.

l. Backing up and steering ability.

m. Stability and protection of cargo.

n. Vegetation impediments.

o. Condition of all stowed items.

p. Adequacy of all safety features and safety instructions.

q. If the specified test requirements are not met, designate the traverse as a mission failure.

r. All questionnaires used and replies given.

s. All repairs, replacements, cleaning and lubricating needed to restore the test item (and the reference vehicle, when used) to the condition it was in at the start of the traverse.

6.3.3.1.3 Multiple Course Traverse - Dry Season-

Record the items described under paragraph 6.3.3.1.2 for each traverse.

6.3.3.1.4 Environmental Storage-

Record the following:

a. The location of the parking site, and the kind of parking used.

b. Daily measurements of the weather conditions during the storage interval.

c. Results of each weekly and monthly inspection.

d. Test item performance at the end of each 3 month storage period. (See item 3 under paragraph 6.2.2.4 c).

e. Color photographs of all corrosion and fungus growth areas.

f. Results of all microbiological analyses.

g. All maintenance and repairs made.

h. Results of the operational test described under paragraph 6.2.2.2 or paragraph 6.2.2.5, as applicable.

i. Extent of deterioration of operating characteristics.

j. The calendar month, day, and hour of the start and finish of the storage period, and of all inspections.

6.3.3.1.5 Single Course Traverse-Wet Season

Record the items described under paragraph 6.3.3.1.2 for each traverse.

6.3.3.1.6 Multiple Course Traverse-Wet Season

Record the items described under paragraph 6.3.3.1.3 for each traverse.

6.3.3.1.7 Durability

Record the items described under paragraph 6.2.2.7.

6.3.3.2 Maintainability

Record the following for each test course traversed, and describe all procedures and special tools used:

a. Active scheduled maintenance times, and the total time required.

b. Active unscheduled maintenance times, and the total time consumed.

c. All other maintenance times.

d. The adequacy of the technical manual.

e. The adequacy of the OEM tools and repair parts.

f. The adequacy of the safety instruction.

6.3.3.3 Reliability

Record the following for each test course traversed, and describe all failures encountered:

a. Chargeable test item failures.

b. Non-chargeable test item failures.

c. Assign each chargeable test item failure into one of the test course categories shown in Table II, as applicable.

d. The MTBF for the test course (See paragraph 6.2.4 a 5).

e. Calculate the probability of mission success for each test course traversed as described in Appendix D.

f. Compare and record the probability of mission success obtained when traversing a multiple course traverse, with the probabilities of mission success obtained when traversing each of the single courses comprising the multiple test course. See paragraph 6.4.4 for an example.

TABLE II

Test Course Categories

Test Course Category	Chargeable Failure Encountered In
1.	A cleared course traverse during the dry season.
2.	An uncleared course traverse during the dry season.
3.	A cleared course traverse during the wet season.
4.	An uncleared course traverse during the wet season.

6.3.3.4 Availability

Record the following for each test course traverse:

a. The inherent availability (A_i) data described under paragraph 6.2.5.1

b. The achieved availability (A_a) data described under paragraph 6.2.5.2

c. Assign each one of the availabilities into one of the test course categories, shown in Table II, as applicable.

6.3.3.5 Safety

Record the safety precautions observed, hazards present, and action taken to alleviate the hazards.

6.3.3.6 Human Factors Evaluation

Complete the task/item checklists by rating the inclusion of each design consideration as satisfactory or unsatisfactory.

6.3.3.7 Value Analysis

a. Record appropriate comments for each of the topics listed below:

1) Mission Capacity.
2) Simplicity.
3) State of the Art.
4) Standardization.
5) Materials and Methods of Construction.
6) Clearances.

b. When making recommendations for changes in test item features or components, record the following:

1) The feature or component under consideration.
2) Recommended change(s)
3) Reason(s) for recommended change(s).

6.3.3.8 Surveillance Tests

Record the following:

a. The condition of the test item just prior to storage, and the storage preparations made, including the shipping containers used.

b. The storage environment and the method of storage.

c. The number of sample groups involved.

d. The duration of storage of each sample group, and the calendar dates of all inspections.

e. The results of all inspections made.

f. All maintenance and repairs made.

g. The extent of deterioration of operating characteristics.

6.3.3.9 Battlefield Day (Tanks and Tracked Vehicles Which Accompany Tanks Only)

Record data following procedures outlined in fuel and oil consumption (MTP 2-3-513).

6.4 DATA REDUCTION

6.4.1 Questionnaires

When two or more persons are asked to fill out a questionnaire giving their opinion regarding specified features in a particular test, and an analysis of variance is used to test for the significance of the variation in the scoring results, perform this analysis as specified in Appendix B.

6.4.2 Checklists

Group the answers to all checklist questions under the applicable headings, such as safety, accessibility, and human factors, and arrange the ansers in the order of their relative importance.

6.4.3 Availability

a. Calculate the inherent and achieved availabilities as follows:

1) Inherent Availability (A_i), is the probability that the equipment, when used under stated conditions, without consideration for any scheduled or preventive maintenance, and in an ideal support environment (i.e., available tools, parts, manpower, manuals, etc), will operate satisfactorily at any given time. A_i excludes ready time, preventive maintenance downtime, supply downtime, and waiting or administration downtime. It is expressed as:

$$A_i = \frac{MTBF}{MTBF+MTTR}$$

where

MTBF = Mean-time between failure;

MTTR = Mean time-to-repair failures.

2) Achieved Availability (A_a), is the probability that the equipment, when used under stated conditions in an ideal support environment (i.e., available tools, parts, manpower, manuals, etc.) will operate satisfactorily at any given time. A_a excludes supply downtime and waiting or administrative downtime. It is expressed as:

$$A_a = \frac{MTBM}{MTBM+\overline{M}}$$

where

MTBM = Mean-time-between maintenance:

$\overline{M}$ = Mean active maintenance downtime resulting from both preventive and corrective maintenance actions.

b. Calculate the lower confidence limit of the MTBF as described in Appendix D. Unless otherwise specified, use a lower confidence level of 90%.

c. Use the following definitions:

1) MEAN TIME BETWEEN FAILURES (MTBF):

MTBF is the total operating time divided by the total number of chargeable equipment failures occuring during the total test period.

2) MEAN TIME TO REPAIR (MTTR):

MEAN TIME TO REPAIR is that portion of the total unscheduled maintenance time which is expended to correct chargeable equipment failures divided by the total number of chargeable equipment failures occurring during the total test period. Maintenance time shall be computed on the basis that the personnel involved in correcting the failure, in addition to the operator or crew, shall be the number of mechanics normally used for the level of maintenance involved, i.e., organizational, direct, or general support maintenance.

3) MEAN ACTIVE MAINTENANCE DOWNTIME ($\overline{M}$):

MEAN ACTIVE MAINTENANCE DOWNTIME is the total preventive (scheduled) and corrective (unscheduled) maintenance time, divided by the total number of preventive (scheduled) and corrective (unscheduled) maintenance actions occurring during the total test period.

4) MEAN TIME BETWEEN MAINTENANCE MTBM:

MEAN TIME BETWEEN MAINTENANCE is the total operating time, divided by the total preventive (scheduled) and corrective (unscheduled) maintenance actions occurring during the total test period.

5) TOTAL TEST PERIOD:

Total test period is the total course traversal time for each for the four test course categories described in Table II , paragraph 6.3.3.3.

6.4.4 Reliability

a. Calculate the probability of mission success for each type of test course traversed for each of the four test course categories described in Table II, paragraph 6.3.3.3, using the procedures described in Appendix D. Unless otherwise specified, use a lower confidence level of 90%.

b. Compare the probability of successfully traversing a multiple course with the combined probabilities of successfully traversing each of the single courses comprising it, as illustrated in the following example:

1) Assume that the following single course probabilities have been obtained:

P_1 = .90 for single course No. 1

P_2 = .85 for single course No. 2

P_3 = .80 for single course No. 3

2) Assuming that the multiple course consists of single courses No. 1, No. 2 and No. 3 connected together, and that the probability of successfully traversing it is designated P_m, the following relationship should be approximately met:

$$P_1 X P_2 X P_3 = P_m$$

or $.90x.85x.80=.61=P_m$

6.4.5 Battlefield Day (Tanks and Tracked Vehicles Which Accompany Tanks Only)

Using data from paragraph 6.3.3.9 calculate the following:

a. Oil (qts) used per gallon of fuel

b. Hrs of engine operation per gallon of oil

APPENDIX A

Tropic Environment Conditions and Effects

The following environmental characteristics are encountered in those Panama Canal Zone areas which are available for testing, and in the Rio Hato Training Area (which is not within the Canal Zone):

a. Weather

1) Under the canopy of heavily-forested areas.

a) Climate category: wet-warm.
b) Temperature, Solar Radiation and Relative Humidity. (see Table I.)

TABLE I

Wet-Warm Climate Temperature, Solar Radiation and Relative Humidity

	OPERATIONAL CONDITIONS			STORAGE AND TRANSIT CONDITIONS	
Local Time	Ambient Air Temperature	Solar Radiation	Ambient Relative Humidity	Induced Air Temperature	Induced Relative Humidity
Hrs.		$Btu/m^2/Hr.$	%		%
0300	See Note 1		100	See Note 2	100
0600			100		100
0900			95		95
1200			95		95
1500		Negligible	95		95
1800			95		95
2100			100		100
2400			100		100
Max.			100		100
Min.			95		95

NOTE: 1. Nearly constant at 25.0°C. (77°F.) to 25.6°C. (78°F.) throughout the 24 hours.

NOTE: 2. Nearly constant at 26.7°C. (80°F.) throughout the 24 hours.

c) Rain: Rainfall is intercepted by the forest canopy and reaches the forest floor as drip and tree runoff.
d) Wind: Light, seldom exceeding 6.42 Km/hr (6 MPH).

2) In the open:

a) Climate category: wet-hot.
b) Temperature, Solar Radiation and Relative Humidity. (see Table II.)

TABLE II

Wet-Hot Climate Temperature, Solar Radiation and Relative Humidity

OPERATIONAL CONDITIONS (See Note 1)							STORAGE AND TRANSIT CONDITIONS (See Note 3)		
Local Time	Ambient Air Temperature		Solar Radiation on a Horizontal Surface	Ambient Humidity			Induced Air Temperature		Induced Relative Humidity
				Relative	Dew Pt.				
Hrs.	°F	°C	Btu/m²/Hr.	%	°F	°C	°F	°C	%
0300	79	26.1	0	100	79	26.1	94	34.4	80
0600	78	25.6	753	100	78	25.6	91	32.8	84
0900	87	30.6	3120	82	81	27.2	117	47.3	74
1200	94	34.4	3870 (see Note 2)	75	84	29.0	150	65.5	30
1500	95	35.0	3120	74	85	29.4	160	71.1	10
1800	90	32.2	753	82	84	29.0	142	61.1	35
2100	83	28.3	0	95	82	27.8	105	40.6	59
2400	80	26.7	0	100	80	26.7	98	36.7	75
Max.	95	35.0	3870	100	85	29.4	160	71.1	85
Min.	78	25.6	0	74	78	25.6	90	32.2	10

NOTES: 1. Four continuous hours with an ambient temperature 1.22 to 1.83 meters (4-6 feet) above the ground surface temperature of 55.6°C. (130°F.), maximum solar radiation (horizontal surface) at a rate of 3870 Btu/m²/Hr. for not more than 4 hours, a windspeed less than 9.27 Km/Hr. (5 knots)

concurrent with the high temperatures, and relative humidity of 74 percent concurrent with the high temperature.

2. A maximum of 4230 Btu/m^2/Hr. has been recorded at Galeta Point.
3. Four continuous hours with an induced air temperature above 68.3°C (155°F.) with relative humidity between 10 and 20 percent, an air temperature extreme of 71.1°C. (160°F.) for not more than 1 hour without benefit of solar radiation and with negligible wind.

c) Rain. A 12-hour rainfall consisting of the intensities shown in Table III.

TABLE III

Wet-Hot Climate Rainfall

Period	Amount	
	cm	Inches
1 minute..............................	1.14	0.45
5 minutes..............................	2.54	1.00
10 minutes..............................	3.81	1.50
1 hour..............................	13.97	5.50
12 hours*..............................	24.13	9.50

*To include each of the shorter period intensities.

Raindrop sizes ranging from 0.6 mm to 4.0 mm with a median of 2.5 mm. The larger drop sizes tend to be associated with the greater intensities.

d) Sea salt fallout. (milligrams of chloride per square meter per day.) Salt fallout will vary from a maximum of 6020 on exposed coasts to a minimum of 36 at inland locations.

e) Windspeed and direction (see Table IV).

b. Terrain

1) Physical Characteristics

a) Abandoned clearings containing stumps and debris caused by slash and burn agriculture.

TABLE IV

Wet-Hot Climate Wind Speed and Direction
(at Cristobal, Canal Zone)

Month	Mean Speed		Prevail Direction	Max. Speed	
	MPH	Km/hr		MPH	Km/hr
Jan	14	22.5	N	34	54.5
Feb	15	24.1	N	32	51.3
Mar	15	24.1	N	30	48.2
Apr	13	20.9	N	37	59.4
May	8	12.8	N	30	48.2
Jun	7	11.2	SE	39	46.5
Jul	8	12.8	N	32	51.3
Aug	8	12.8	W	35	56.0
Sep	6	9.6	SE	31	49.7
Oct	7	11.2	SE	32	51.3
Nov	8	12.8	W	38	60.9
Dec	11	17.7	N	35	56.0

b) Lowlands ditched or channeled for irrigation, or for malaria control purposes. (This kind of terrain is employed only in extreme cases.)
c) Small, steep-sided streams, or dry gullies, as close as 0.4 kilometers (1/4 mile) apart, subject to sudden flash floods.
d) Soils.

1. Lateritic type, rich in iron or aluminum.
2. Alluvial type.
3. Loam type.

e) Maximum altitude - 244 meters (800 feet).

2) Vegetation characteristics.

a) Gallery forest along water expanses.
b) Mature semi-evergreen tropic forest with relatively light undergrowth.
c) Early second-growth semi-deciduous tropic forest with dense undergrowth.
d) Mature closed canopy tropic forest with little or no undergrowth.

e) Early second-growth tropic evergreen forest with dense undergrowth.

f) Tropic savannas of short grass with patches of stunted trees. The soil is too sandy or too shallow to support a rain forest, or has been burned annually.
g) Tropic trees with above-the-ground stilt roots or buttresses.
h) Lianas (woody vines).
i) Jungle air plants.
j) Parasitic jungle plants, fungi and algae.
k) Tropic swamp forests.

1. Red, white, and black mangrove.
2. Palm.
3. "Catival".
4. Coastal thicket.

l) Tropic marshes containing tough, thick reed up to 4.57 meters (15 feet) tall, forming a solid mass of vegetation.

3) Biological characteristics.

a) Destructive insects.
b) Bacteria.
c) Fungi.

The following are some of the conditions encountered, and the expedients which have been used, during off-road tests of towed, wheeled, and tracked combat vehicles.

a. Dry gullies may be found to be very difficult to cross. In many instances, vehicles cannot cross the gullies without extensive effort, such as winching up the bank slope.

b. In the jungle and rain forests, maneuverability and speed are greatly reduced, because a trail must often be cleared of trees, vines, and underbrush, to permit vehicle passage. In many areas, a lightweight tracked vehicle can negotiate a path between trees; however, vehicles wider and less maneuverable may not be able to move until the small trees are pushed down by force, or the large trees are cut and removed from the trail. Trees with buttress and stilt roots pose a major problem in the rain forests. Frequently, portions of the buttress roots may have to be cut away, and stilt-rooted trees usually have to be cut down to permit vehicle passage. In some areas fallen tree trunks, lying either on the ground or against other trees, must be moved aside.

c. Overhanging limbs and lianas are a hazard to personnel and equipment being carried in open vehicles, and poisonous plants and insects that produce skin irritations may be encountered.

d. Average cross-country speeds (excluding immobilizations) may

be 14.5 kilometers per hour (9 miles per hour) in level lowland grassy areas, 4.8 kilometers per hour (3 miles per hour) on hilly forest trails, and 1.6 kilometers per hour (1 mile per hour) when traversing undisturbed forest areas.

e. An off-trail test through a tropic forest with dense undergrowth is considered one of the most meaningful tests of overall vehicle mobility in a second-growth tropic forest. This is because each vehicle is "on its own", with no help from precutting and impedement vegetation or other preparation of terrain, except that steep slopes and stream crossings are avoided.

f. Many vehicles, tracked and wheeled alike, may not be able to negotiate slopes over 40 to 50 percent, because heavy rainfall leaves the soil surfaces wet and slippery.

It is very difficult to estimate the rate of movement of infantry over jungle terrain. The data in Table V must be used with caution, keeping in mind that accurate estimates can be made only through experience with a knowledge of troop capabilities. In the following table, substantially level terrain is assumed.

Movement through bamboo is slow and arduous. Men used as cutters and trail breakers should be relieved at five to ten minute intervals. Because of this, and because movement is very noisy, bamboo growths should be avoided or bypassed, if possible.

Environmental characteristics in the wet-warm and wet-hot climate areas in other parts of the world are described in AR 70-38 and FM 31-30.

A tropic rain forest to be considered authentic requires 12 months of heavy rain a year. The minimum yearly rainfall should be about 305 centimeters (120 inches). It must also have at least 20.3 centimeters (8 inches) of a rain a month, normally. Most genuine rain forests get much more than these amounts. Annual rainfalls of 508 to 762 centimeters (200 to 300 inches) are common, and they may reach 1016 centimeters (400 inches) or more in some parts of the tropics.

TABLE V

Infantry Rate of Movement

Terrain	Average Speed Km/hr	Average Speed MPH	Speed Retarding Obstacles
Uncleared primary rain forest	0.97	0.6	Gullies, streams, rivers
Uncleared secondary rain forest	0.48	0.3	Gullies, streams, rivers
Uncleared swamps	0.10 to 0.48	0.06 to 0.3	-------------
Savanna (grass land)	0.48	0.3	-------------
Bamboo clusters	*	*	-------------
Cleared open country	3.2 to 4.8	2.0 to 3.0	Gullies, streams, rivers

*Extremely slow

If the rainfall is not consistently steady and heavy all year around; that is, if there are distinct wet and dry seasons, a semi-deciduous forest may result, provided the soil is not too sandy or too shallow to support such a growth.

When the patterns of climate, terrain, and deterioration of materials are superimposed on the earth's surface, their boundaries coincide to a remarkable degree. There is a definite correlation between climate and deterioration of materials, and an even more definite correlation between terrain and problems of operation and maintenance resulting from deterioration of materials. A knowledge of these patterns of climate, therefore, is the first step in understanding problems associated with the deterioration of materials and the design, operation, and maintenance of equipment. The full range of military environments is included in MIL-STD-210.

Tropic climates are generally defined as those in which the mean monthly temperature never goes below 18.3°C. (64.9°F.). The outstanding common characteristics of tropic regions are high ambient temperatures and high humidity. These two conditions cause most problems of deterioration and of design, operation, and maintenance.

The following major problems are associated with tropic areas: corrosion of steel, copper alloys, magnesium, aluminum and zinc, caused by electrolytic action; fungus growth on organic materials, such as canvas, felt, gasket materials, and sealing compounds, and even on organic matter accidentally deposited on the surfaces of optical elements of fire-control equipment; deterioration through corrosion and fungus growth in insulation, generating and charging sets, demolition and mine-detection equipment, meters, dry cell batteries, storage batteries, cables, and a variety of lesser components. Termites may attack all wooden parts not impregnated with a repellent agent and are especially attracted by plywood bonded with a vegetable glue. Termites will also attack anything that is cellulosic such as canvas, rope, paper, etc. They will also penetrate, but not eat, plastics and soft metals.

Corrosion, rotting and weakening of materials can be caused by fungus. For example, gasoline and diesel fuels in contact with water, such as fuel spillage on the outside surface of a metallic fuel tank which is later rained upon, will, in a few days, display considerable fungus growth and corrosion of the tank surface. Materials inert to the growth of fungi should, therefore, be used whenever possible in the design of US Army equipment.

In general, synthetic resins such as melamine, silicone, phenolic, flurinated ethylenic polymers with inert fillers such as glass, mica, asbestos and certain metallic oxides provide good resistance to fungus growth. Materials which are non-resistant to fungi are listed in Table VI. As shown in this table, not all rubber is fungus resistant, and antifungus coatings generally are impractical for this material. When fungus resistant rubber is needed, it should be so specified to insure that the manufacturer furnishes a suitable compound.

When designing equipment to resist fungi, in general, it is not significant whether a specific kind of fungus is present in a given geographical location. But it is significant to know that any susceptive material is going to be degraded microbiologically whenever the temperature and humidity are suitable for microbrial growth. It may or it may not be of the same species of fungi in Florida, New Guinea, or Europe, but, regardless of location, there are fungi there which can do the damage. The materials in Table VI are susceptible to fungus attack.

Materials used should be corrosion-resistant or should be protected by plating, painting, anodizing, or by some other surface treatment to resist corrosion. Surfaces required to be acid-proof should be given additional surface treatment. Metal surfaces not painted should be protected by other suitable means, e.g., encapsulating. The use of any protective coating that is less prone to degradation by environmental extremes should be used when possible.

It is difficult to make definite comparisons of the corrosion-resistant properties of metals, since their resistance varies with the chemical

environments. Metals commonly used in vehicle design for their corrosion resistant properties are titanium, molybdenum alloys, stainless steel, cadmium, chromium, nickel and tin.

The aluminum and magnesium alloys are seriously degraded by corrosion and should be avoided.

TABLE VI

Fungus-Susceptible Materials

Cork	Felt, hair	Paper and cardboard
Cotton, duck and twill	Leather	Phenolic resin compound with cellulose filler
Duck, cotton	Linen	
Felt, wool	Melamine resin compound with cellulose filler	Wool
Plastic materials using cotton, linen, or wood-flour as a filler, notably the general purpose (Type PBG) grade.	Paints	Adhesives
	Lubricating oils	Fabrics
	Gasoline & diesel fuels	Rope
Rope, natural fibre	Thread, twine, natural fibre	Wax
Rubber (only certain compositions)	Webbing, cotton	Wire insulation

Dissimilar metals far apart in the galvanic series (Table VII) should not be joined directly together. If they must be used together, their joining surfaces should be separated by an insulating material, except if both surfaces are covered with the same protective coating. Care should be taken to assure that no other electrical path will be established between dissimilar metals (i.e., a wire from one bolt to another, etc.).

The high solar radiation encountered in exposed areas in the Panama Canal Zone may create many of the following maintenance problems: heat can lead to difficulties with electronic and electrical equipment, especially if these have been designed for moderate climates; materials such as waxes, soften, lose strength, and melt; materials may lose mechanical or electrical properties because of prolonged exposure; fluids may lose viscosity; joints that would be adequate under most other conditions may leak. Heat can also cause the progressive deterioration of many types of seals found in transformers and capacitors. Capacitors of some types develop large and permanent changes in capacity when exposed to temperatures above 49°C. (120°F.).

The following factors should also be considered:

1) Dry cells have a short life in hot environments, and, at temperatures above 35°C. (95°F.), deteriorate rapidly.
2) Wet batteries lose their charge readily.
3) Tires and track pads wear out rapidly.
4) Paint, varnish, and lacquer crack and blister.
5) Objects exposed to solar radiation can obtain temperatures of 63.8°C. (145°F.) or higher, and high temperatures accelerate some of the chemical reactions which produces degradation. A rule of thumb is that a rise of 10°C. (18°F.) doubles the speed of reaction.

TABLE VII

Galvanic Series of Metals and Alloys

Group	Metal
I	Magnesium Magnesium alloys
II	Zinc Galvanized iron or steel Aluminum (5058, 5052, 3004, 3003, 6063, 6053)
III	Cadmium Cadmium plated iron or steel Mild steel Wrought iron Cast iron Ni resist Lead-tin solders Lead Tin
IV	Chromium Admiralty brass Aluminum bronze Red brass Copper Silicon bronze Phosphor bronze Berylium copper Nickel Inconel Monel Type 400 corrosion resisting steel Type 300 corrosion resisting steel Titanium
V	Silver Gold Platinum

Cathodic End (least susceptible to corrosion)

Table VIII gives a summary of the major environmental effects caused by exposure to the Panama Canal Zone climate.

The effects of high humidity and fungus growth can be substantially eliminated by storing the test item in a suitably air-conditioned land-based or shipborne storage area. However, the test item shoud be subjected to the worst environmental conditions, which occur when it is being operated, and parked, without environmental protection, in the terrain areas for which it was designed, for the terrain mileages and the time durations specified.

Surveillance testing is used to determine whether any of the materials used in the construction of the test item will lose their functional utility after prolonged exposure to the environment in which the test item is located. This testing is accomplished by storing the test item in this environment, and testing it on a continuing basis to determine the extent of deterioration as compared with the original requirements.

TABLE VIII

Summary of Major Environmental Effects

Environmental Factor	Principal Effects	Typical Failures Induced
High temperature	Thermal aging:	Insulation failure
	Oxidation	Alteration of electrical properties
	Structural change	
	Chemical reaction	
	Softening, melting and sublimation	Structural failure
	Viscosity reduction and evaporation	Loss of lubrication properties
	Physical expansion	Structural failure
		Increased mechanical stress
		Increased wear on moving parts

TABLE VIII (Continued)

High relative humidity	Moisture absorption	Swelling, rupture of container
		Physical breakdown
		Loss of electrical strength
	Chemical reaction	Loss of mechanical strength
	Corrosion	Interference with function
	Electrolysis	Loss of electrical properties
		Increased conductivity of insulators
	Dimensional instability	Warping surfaces
Solar radiation	Actinic and physico-chemical reactions:	Surface deterioration
		Alteration of electrical properties
	Ozone formation	Discoloration of materials
		Embrittlement
Salt spray	Chemical reactions:	Increased wear
	Corrosion	Loss of mechanical strength
		Alteration of electrical properties
		Interference with function
	Electrolysis	Surface deterioration
		Structural weakening
		Increased conductivity
Wind	Force application	Structural collapse
		Interference with function
		Loss of mechanical strength
	Deposition of materials	Mechanical interference and clogging
		Abrasion accelerated

TABLE VIII (Continued)

Rain	Physical stress	Structural collapse
	Water absorption and immersion	Increase in weight Aids heat removal Electrical failure Structural weakening
	Erosion	Removes protective coatings Structural weakening Surface deterioration
	Corrosion	Enhances chemical reactions
Water immersion	Corrosion of metals	Structural weakness, seizure of parts, contamination of products
	Chemical deterioration	Dissolving out and changing of materials
	High pressures	Mechanical damage
Insects and bacteria	Penetration into equipment	Blockage of small parts, meters, etc.
	Nibbling by termites	Damage to plastic cables or other organic insulating materials, causing shorts
	Spinning webs or cocoons, or depositing eggs, egg cases, or droppings	Electrical shorts
Fungi	Growth of molds, hyphae	Damage to optical equipment; leakage paths in high impedance circuits; blockage of small parts, meters, etc.; breakdown of mechanical strength of all organic materials

TABLE VIII (Continued)

Ozone	Chemical reactions:	Rapid oxidation
	Crazing, cracking	Alteration of electrical properties
	Embrittlement	Loss of mechanical strength
	Granulation	Interference with function
	Reduction of dielectric strength of air	Insulation breakdown and arc over

APPENDIX B

Questionnaires

I. GENERAL

Questionnaires are designed to obtain information from test personnel regarding specific items they are asked to comment on, such as the operability, convenience, and comfort of a test item and, when a reference item is also operated alongside the test item, their opinion as to the relative merits of the two.

The following discussion and example may be used as a guide in preparing, and evaluating, a questionnaire for each feature of the test item for which the opinion of the user personnel is desired.

II. THE DESIGN

Results of experiments are frequently classified according to the supposed contributions to the results. Thus, if we are testing a particular item under different environmental conditions, with several different technicians doing the rating, we may let y_{ij} be the score given to the item by the ith technician in the jth "environment".

For example, it may be felt that a technician can assign (in a reproduceable manner) the following grades to the item:

1. Very poor.
2. Poor.
3. Average.
4. Good.
5. Very good.

Thus, the more desirable the technician feels that the item is, the larger the number he will assign to it. Suppose further that we have six different courses around which the technicians will drive the item in order to judge them, and that these courses are designed to represent the following environments:

TABLE I

The Test Courses

Course	Environment (cleared terrain test course)
1	Hilly region in an early second-growth forest.
2	A relatively level early second-growth forest with gullies or shallow streams to be crossed.
3	A relatively level early second-growth forest with a river to be crossed.
4	An upland area of steep grass slopes substantially devoid of trees.
5	Mature closed canopy lowland rain forest.
6	Flat open grass lands.

If we have six test drivers, and each driver goes over each of these six courses, we would have 36 different ratings, or y_{ij}'s. However, it may be too expensive or inconvenient to get as many as 36 different ratings, and 24 may be the largest number of ratings that is feasible. Of course, the more ratings made, the more accurate will be the knowledge gained from the experiment, but there are other ways, besides enlarging the number of readings, which will increase the information obtained; particularly, the design of the experiment which will insure that resources are used to the best advantage. The advice of a qualified statistician should be sought when any question of how to design an experiment is raised.

In the case at hand it appears that a very worthwhile design which would produce 24 different ratings, might be the following one:

TABLE II

The Course Allotments ("Block Design")

Courses \ Drivers	1 4	2 5	3 6
1	X	X	
2	X		X
3		X	X
4	X		X
5		X	X
6	X	X	

That is, drivers 1 and 4 would go over courses 1,2,4 and 6; drivers 2 and 5 would go over courses 1,3,5 and 6; and drivers 3 and 6 would go over courses 2,3,4 and 5.

Assuming this method of scoring, and this design, the results of the experiment may be as shown in Table III.

It seems worthwhile to note one particularly nice property of this design; the fact that a number of the drivers do exactly the same things. This would make it possible to instruct the drivers in groups, and so carry out the experiment with a minimum of confusion.

It should be understood that the particular block design with six courses and six men, described above, is only one of a large number of block designs which can be devised. A qualified statistician can supply a design to fit almost any physical situation if he is consulted in the planning stage of the experiment.

An individual driver's gradings will probably not be completely reproducible; that is, if he grades the same item on the same course several different times, he will probably not always give the course the same score, but will tend to give scores which fall in a regular manner about the actual value for that course. This last is called the error contribution to the score.

TABLE III

Driver Rating Results

Driver \ Course	1	2	3	4	5	6	Total	Mean
1	2	5		1		4	12	3.00
2	3		4		4	3	14	3.50
3		4	5	1	2		12	3.00
4	1	4		3		2	10	2.50
5	5		2		2	1	10	2.50
6		4	2	5	3		14	3.50

The use of block designs involves analysis of variance, which is a test of significance for variation in experimental conditions. Variance ratios, as for example.

$$\frac{\text{variation due to terrain environment}}{\text{variation due to experimental error}}$$ (disagreement among raters during same course)

can be computed, and then compared to values obtained from statistical tables, in order to decide whether the observed variation is due to the terrain environment, or experimental error. These computations should be performed by a qualified statician. See item Y under 4 "REFERENCES" for assistance in this matter.

APPENDIX C
Checklists

The following checklist questions are presented under two categories. The first category, entitled "Tropic Environment Considerations", deals with those features which are emphasized in a tropic environment. The second category, entitled "General Considerations", deals with those features which are substantially independent of the kind of climate involved.

I. TROPIC ENVIRONMENT CONSIDERATIONS

a. Are all ventilating louvres provided with baffle plates and/or do the louvres have reverse-curvature bends to impede the entrance of moisture?

b. Are adequate drain holes provided to drain off moisture inside closed-off areas, caused by condensation due to temperature changes when exposed to high humidity conditions?

c. Have appropriate precautions been taken to reduce the effect on test item operation due to clogging of ventilating screens or water-cooling radiators?

d. Are provisions such as shielding, insulation or warning labels provided when the temperature of surfaces with which personnel may come in contact exceeds 45°C (115°F)?

e. Is adequate protection provided on the test item to protect personnel, equipment and cargo from overhanging limbs and lianas?

f. Are provisions made on the test item to protect the operator/crew from the effects of prolonged exposure of the test item to the direct rays of the sun?

g. Is a suitable medical kit provided for on-the-site treatment against poisonous plants, insects or animals?

h. Is hermetic sealing used to keep out moisture whenever possible?

i. Is contact between corrodable metal parts and anti-fungus-treated materials avoided whenever possible?

j. Are drain holes provided, and are chassis and racks channeled to prevent moisture traps?

k. Is air-conditioning provided whenever possible if the ambient temperature exceeds 32.2°C (90°F)?

l. Is proper ventilation provided where personnel are performing monitoring, servicing, or other maintenance tasks?

m. Are reflecting surfaces used on equipment which must be maintained while exposed to the sun?

n. Are materials used to the greatest extent possible for their non-corrosive and non-hygroscopic characteristics, as well as their ability to resist fungus growth?

o. Are materials used which inhibit fungus growth rather than materials which include a fungicide, or which have received surface fungistatic or fungicidal treatment?

p. Are metallic parts designed without recesses, cups or traps where liquids can accumulate, and are metals in contact chosen as close together as possible in the electromatic force series?

q. Are exposed surfaces completely covered with some form of protective coating or surface plating?

r. Are corrosion inhibitors or preservative materials used where necessary or possible?

s. Are synthetic rubbers which are resistant to both microbiological and ozone deterioration, used wherever possible?

t. Are tarpaulins and cab tops shaped and supported to shed waste, and preclude formation of water pockets, whether the vehicle is parked or in operation?

II. GENERAL CONSIDERATIONS

A. ACCESSIBILITY AND HUMAN FACTORS

1. Is optimum accessibility provided for all items requiring maintenance, inspection, removal, or replacement?

2. Is a transparent window or quick-opening metal cover used for visual inspection accesses?

3. Are access openings without covers used where this is not likely to degrade performance?

4. Is a hinged door used where physical access is required (instead of a cover plate held in place by screws or other fasteners)?

5. If lack of available space for opening and access prevents use of a hinged opening, is a cover plate with captive quick-opening fasteners used?

6. If a screw-fastened access plate is used, are no more than 4 screws used?

7. On hinged access doors, is the hinge placed on the bottom, or is a prop

provided so that the door will stay open without being held if unfastened in a normal installation?

8. Are parts located so that other large parts which are difficult to remove do not prevent access to them?

9. Are components placed so that there is sufficient space to use tools without difficulty?

10. Are units placed so that structural members do not prevent access to them?

11. Are components placed so that all throw-away assemblies or parts are accessible without removal of other components?

12. Is the item designed so that it is not necessary to remove any assembly from a major component to troubleshoot to that assembly?

13. Can screwdriver-operated controls be adjusted with the handle clear of any obstruction?

14. Are units laid out so maintenance technicians are not required to retrace their movements during equipment checking?

15. Is enough access room provided for tasks which necessitate the insertion of two hands and two arms through the access?

16. If the maintenance technician must be able to see what he is doing inside the equipment, does the access provide enough room for the technician's hands or arms and still provide for an adequate view of what he is to do?

17. Are irregular extensions, such as bolts, and hoses, easy to remove before the unit is handled?

18. Are access doors made in whatever shape is necessary to permit passage of components and implements which must pass through?

19. [illegible] the installation along a straight or moderately- [illegible]

20. [illegible] its (more than about 13.4 kilograms (25 lbs) installed within [illegible] of [illegible] for purposes of replacement?

21. Are provisions made for support of units while they are being removed or installed?

22. Are rests or stands provided on which units can be set, to prevent damage to delicate parts?

23. Are access points individually labeled so they can be easily identified with nomenclature in the job instructions and maintenance manuals?

24. Are accesses labeled to indicate what can be reached through this point (label on cover or close thereto)?

25. Are accesses labeled to indicate what auxiliary equipment is needed for service, checking, etc., at this point?

26. Are accesses labeled to specifiy the frequency for maintenance either by calendar or operating time?

27. Are access openings free of sharp edges or projections which could injure the technician or snag clothing?

28. Are parts which require access from two or more openings marked to so indicate, in order to avoid delay and/or damage by trying to repair or remove through only one access? Are double openings of this type avoided whenever possible?

B. SERVICING AND HUMAN FACTORS

1. Are standard lubrication fittings used so that no special extensions or fittings are required?

2. Are standard lubricants that are already in the Federal Supply System specified?

3. Are adequate lubrication instructions provided that identify the frequency and type of lubricants required?

4. Are fluid replenishing points located so that there is little chance of spillage during servicing, especially on easily-damaged equipment?

5. Are filler openings located where they are readily accessible, and do not require special funnels?

6. Are air reservoir safety valves easily accessible, and located where pop-off action will not injure personnel?

7. Are fuel tank filler necks, brake air cocks, flexible lines or cables, pipe runs, fragile components and like items positioned so they are not likely to be used as convenient footholds or handholds, thereby sustaining damage?

8. Where bleeds are required to remove entrapped air or gases from a fuel or hydraulic system, are they located in an easily-operable and accessible position?

9. Are drains provided on all fluid tanks and systems, fluid-filled cases or pans, filter systems, float chambers, and other items designed or likely to contain fluid that would otherwise be difficult to remove?

10. Are drain fittings of few types and sizes used, and are they standardized according to application throughout the system?

11. Are valves or petcocks used in preference to drain plugs? Where drain plugs are used, do they require only common hand tools for operation, and does the design ensure adquate tool and work clearance for operating?

12. Are drain cocks or valves clearly labeled to indicate open and closed positions, and the direction of movement required to open?

13. Do drain cocks always close with clockwise motion and open with counter-clockwise motion?

14. When drain cocks are closed, is the handle designed to be in down position?

15. Are drain points placed so that fluid will not drain on the technician or on sensitive equipment?

16. Are drain points located at the lowest point when complete drainage is required, or when separation of fluids is desired (as when water is drained out of fuel tanks)?

17. Are drain points located to permit fluid drainage directly into a waste container without the use of adapters or piping?

18. Are drain points placed where they are readily operable by the technician?

19. Are instruction plates provided, as necessary, to ensure that system is properly prepared prior to draining?

20. Are lubrication requirements reduced to two types, if possible; one for engine lubrication and one for gear lubrication?

21. Are the same fuels and lubricants used in auxiliary or mounted equipment as in prime unit, where practical?

22. Are easily-distinguished or different types of fittings used for points or systems requiring different or incompatible lubricants?

23. Are pressure fittings provided for the application of grease to bearings that are shielded from oil?

24. Is ample reservoir space provided for grease to bearings in gear unit?

25. Is provision made for a central lubrication or filler point, or a minimum number of points, to all areas requiring lubrication within a given system or component?

26. Are service points provided, as necessary, to ensure adequate adjustment, lubrication, filling, changing, charging, and other services to all points requiring such servicing?

27. Are oil filler caps designed so that they:

    a. Snap, then remain open or closed?
    b. Provide large round opening for oil filling?
    c. Permit application of breather vents, dipsticks, and strainers?
    d. Use hinges rather than dangerous chains for attaching the lid?
    e. Are located external to enclosure, where possible, to eliminate necessity for access doors, plates, or hatches?

28. Is there adequate hand, leg, foot, and body access to all points requiring servicing or operation?

29. Are sufficient and adequate towing, hoisting, lifting, and jacking facilities provided?

30. Are batteries located for rapid servicing and replacement?

C. VEHICLES AND HUMAN FACTORS

1. <u>Engines</u>

    a. Are means provided for manually cranking the engine?
    b. Are engine timing marks visibly accessible?
    c. Do engine timing marks have a reference point on the engine to permit a timing check when the engine is installed in the vehicle?
    d. Are breathers easy to remove and replace?
    e. Are engine governors made tamperproof?
    f. Are fan belts and other drives requiring adjustment simple and readily accessible?
    g. Does the oil drain plug drain the pan completely, without requiring the operator to move the vehicle?
    h. Is the distributor or fuel injector located in an accessible and unobstructed location?
    i. Are fuel and oil filters located so they can be cleaned and replaced without disassembly of other parts of the vehicle?

2. <u>Drains and Vents</u>

    a. Does the vehicle have drain valves with simple, accessible, and dependable operating mechanisms?
    b. Are vents and drains designed to prevent clogging from mud, dirt, or other contamination?
    c. Are drain plugs and valves designed to resist seizing, either in the open or closed position?
    d. Are all drain plugs of the same size, and do they have a socket (recess) to permit removal by a common hand tool?
    e. Are drains designed to empty components completely of lubricants and hydrualic fluids?
    f. Do drained fluids drain unobstructed to the outside of the vehicle, without special equipment, and without splashing onto vehicle components?

g. Are pneumatic system reservoir purging drains readily available to the operator, and do they drain the tanks completely?
h. Are means provided to remove water from cab and cargo body with vehicle either under way or at rest?
i. Are drains and vents located where they can be cleaned and checked easily by crew members?
j. Are drains and vents capable of easy identification, and located to allow closing and checking prior to operation of floating or swimming vehicles?
k. Are instruction plates provided showing procedure and location for drains and vents on floating or swimming vehicles?
l. Are drain operating handles designed to be down when in closed position?

3. Batteries

a. Are storage batteries capable of being exchanged by one man in no more than ten minutes, using on-vehicle equipment only?
b. Are batteries and their compartments capable of being cleaned and serviced without removal of other components?
c. Are battery retaining devices secured with fasteners that can be removed without hand tools, or provided with the same bolt or nut size as the battery terminal clamps?
d. Are batteries mounted on roll-out racks, slides, or hinges, and is it convenient to extend these components without disconnecting them?
e. Are battery access covers fastened with quick-release fasteners, and is the mounted position of the access cover obvious? Where a hinged cover is used, is sufficient clearance allowed for opening the door?

4. Canvas and Accessories

a. Are tarpaulins and bows covering the bed of cargo vehicles capable of providing a 191 centimeter (75 inch) clearance from the cargo floor to provide head clearance for men working inside the vehicle?
b. Is one man able to gain access to the cargo compartment from front or rear, with a tarpaulin and curtains in place, within three minutes?
c. Are tarpaulin bows, ropes, and snaps easy to unfasten? Are bows easy to remove from sockets?
d. Are tarpaulin bows (especially wooden ones) designed to resist seizing in their sockets because of moisture, rust, or dirt?
e. Is the cab capable of conversion from open to closed type, and vice versa, by one man in ten minutes or less?
f. Are tarpaulin, end curtains, and bows capable of being removed or installed by two men in no more than ten minutes?
g. Are pins and other retaining devices provided with the largest working clearances which will still permit them to be retained properly?
h. Are retaining chains provided to prevent the loss of retaining pins and small removable items?

5. Radiators

a. Is filler neck size compatible with existing fillers for efficiency of filling?
b. Is the drain readily accessible?
c. Is the filler neck positioned so that the operator can see the fluid level inside the tank? Is the necessity to add fluid to determine level eliminated?
d. Are upper and lower hose connectors located to provide sufficient hand clearances for removal and replacement of hoses?
e. If lower echelon of maintenance is intended (through direct support level), is silver solder avoided in the construction of the radiator to facilitate repair?

6. Intervehicular Connections

a. Are intervehicular cables of adequate length so as not to restrict maneuverability of towing vehicle when vehicles are coupled together under any applicable conditions?
b. Are suitable provisions made to prevent damage to intervehicular cables in use?
c. For vehicles equipped with air-over-hydraulic or air brakes, are suitable provisions provided for connecting to the brake system of another vehicle at the front and rear, and for controlling brakes of a vehicle being towed by another truck during emergency operation?
d. Are brake hoses or cables long enough to permit unrestricted maneuverability of the prime mover or a towed vehicle when coupled together, under any applicable conditions?
e. Are suitable provisions made to prevent kinking, entanglement, dragging, abrasion, or pinching of the brake lines?
f. Whenever practicable, are the wheels of a towed vehicle designed to be interchangeable with those of its normal prime mover?

7. Tires

a. Are spare tires and servicing tools readily available and capable of being removed and stowed by one man, using only OVE (on vehicle equipment)?
b. Is a pneumatic outlet and OVE pressure gauge provided to inflate and reduce pressure in vehicle tires on any vehicle employing air-over-hydraulic brake system?
c. Is the air hose of sufficient length to reach tires, including the spare tire?
d. Is the spare tire capable of being inflated and checked in the mounted position by a standard air gauge?
e. Are dual tires designed to allow the inflating and checking of air in both the outer and inner tire, and does this valve location enable the tires to be inflated and checked when tires are interchanged?
f. Is equipment used to stow and unstow spare tires simple to operate, and pose no possibility of injury to personnel?

g. Is the spare wheel capable of being removed and replaced with vehicle fully loaded?

D. SAFETY

1. General

a. Is the item designed so that the center of gravity, configuration, and location of legs and supports make it unlikely to tip over from unbalance or strong wind?
b. Are expandable and collapsible structures such as shelters, jacks, supports, masts, tripods, etc., free of projections, sharp edges, or design features which might be hazardous to personnel?
c. Are lifting rings or slings provided for an item which is normally moved or lifted by machine?
d. Are ladders, climbing rings, handholes, rails, walkways, etc., provided where needed?
e. Are steps and ladders and methods of supporting them safely made?
f. Are entrances to enclosures free of hazardous obstructions?
g. Do floor surfaces provided adequate non-slip characteristics?
h. Are fastenings and methods of securing equipment to walls and racks sufficiently strong to prevent break-away and falling?
i. Are [illegible]afety measures provided in the event the trailer becomes de-[illegible]d from the towing vehicle?
j. [illegible] semitrailers are detached from towing vehicles do dolly wheels or [illegible]nding gear provide adequate support?
k. [illegible] standard military vehicle has been modified to accomodate the equipment, is the vehicle still capable of satisfactory and safe operation?
[illegible] Do doors and hinged covers have positive-acting hold-open devices?
m. Are locking mechanisms for doors designed to prevent injury to the operator when the lock is released?
n. Is the method of opening a cover evident from the construction of the cover? If not, is an instruction plate permanently attached to the outside of the cover?
o. Is it evident when a cover is in place but not secured?
p. Are lifting handles located over center of gravity whenever possible?
q. Are doors and other openings free of hazards from improperly-designed catches, hinges, supports, fasteners, and stops?
r. Are heavy parts located as close as possible to load-bearing structures, and as low as possible?
s. Is the weight distribution such that the item is easy to handle, move, or position?
t. Are tasks of operation and maintenance such that they do not require excessive physical strength?
u. Is the item free of sharp or overhanging edges and covers that might cause injury to personnel?
v. When glass is used, is it glareproof and shatterproof?
w. Do exposed gears, cams, levers, fans, belts or other reciprocating, rotating or moving parts have adequate safety covers?

x. When required, are provisions made for protection against eye hazards from flying particles?
y. Are components located where dirt or oil will not drop on them or on the technician performing maintenance tasks?
z. Are potential mechanical hazards adequately treated in the instructional manual?
aa. Are tarpaulins and end curtains inherently fire resistant, or treated to be fire retardant?

2. Miscellaneous

a. Have fire and explosion hazards been kept to a minimum by use of proper components?
b. Are fire extinguishers provided and mounted in easily accessible locations?
c. Are fire extinguishers the proper type for the equipment and for the overall installation?
d. Are properly-marked fire exits provided in shelters, when required?
e. Have precautions been taken to assure that the storage and distribution of flammable material is done safely?
f. Is a self-closing metal can provided for oily rags and waste where required?
g. Does the illumination enhance safety by providing?

1. Suitable brightness for the task?
2. Uniform lighting on the task?
3. Suitable contrast between task and background?
4. Freedom from glare from illuminant or surfaces?
5. Suitable quality and color?

h. Do warning lights provide sufficient contrast with ambient illumination levels?
i. Is the item designed to prevent extraneous light escape?
j. Does the ventilating system provide for operator safety by ducting excess heat liberated by the item to the outside air?
k. Is the cooling air for compartment-mounted equipment completely separated from the personnel space to prevent contamination of the surrounding air?
l. Are adequate precautions made to prevent exposure of personnel to respiratory hazards from toxic gases, dusts, fumes, and mists?
m. Is the air intake isolated from the exhaust?
n. Is the compartment ventilating system designed to safeguard against depletion of oxygen in the personnel area?
o. Are all air flow paths free of obstruction?
p. Is compartment-mounted equipment furnished with test kits for checking air contamination and oxygen depletion?
q. Are acids or other harmful liquids properly identified with appropriate caution notices?
r. Do instructions specify type of cleaning fluid and precautions to be taken when cleaning equipment?

s. Are adequate safety devices and safety instructions provided for handling and use of gases stored under high pressure?
t. Is protection provided against hot surfaces which might be dangerous to personnel?
u. When necessary, are ear and eye protective devices provided?
v. Is the ambient noise level acceptable for personnel safety and efficiency?
w. Is the equipment provided with sufficient caution plates to warn maintenance personnel of potential safety hazards?
x. Are all safety requirements of applicable specification or technical requirement complied with?
y. Are potential hazards adequately treated in the instruction manual?

APPENDIX D

Reliability Calculations

NOTE: The following assumptions are made in this Appendix:

1) Every traversal in each test course category occurs under identical weather and terrain conditions.
2) The operating condition of the test item is identically the same at the beginning of each test course traverse.
3) Vehicles which experience a chargeable failure (see paragraph 6.2.4 a) during a given mission test are not replaced when calculating the probability of mission success described under Section III below.
4) All vehicles tested are identically the same in design and construction.

I. Lower Confidence Limit of MTBF - Exponential Failure Distribution

NOTE: The following procedure for determining the confidence limit for the MTBF is applicable only when the failure distribution is exponential (constant failure rate). If the failure distribution is not known, or if it cannot be reasonably assumed to be exponential, proceed as described under II below.

a. Calculate the lower 90% confidence limit using the following equation:

$$m = \frac{2T}{\chi^2_{\alpha;\nu}} \qquad (1)$$

where m = lower limit of the MTBF at 90% confidence

ν = 2(r+1)= number of degrees of freedom

α = the likilihood that the statement is incorrect. (this is 1 - .90 = .10 when the confidence level is 90%)

$\chi^2_{\alpha;\nu}$ = the value of χ^2 for the given value of ν per Table H-3 in AMCP 702-3

T = sum of the operating times accumulated by all test items in the test course category

and r = total number of chargeable test item failures. (see paragraph 6.2.4 a. 1) and 6.2.4 a. 2) above).

Example: Five vehicles are placed on test. The total operating time accumulated by these five test items while traversing all of the category 1 test courses (see paragraph 6.3.3.3) is 200 hours. Five chargeable failures are observed during this time interval. Find (a) A point estimate of the MTBF of the vehicle (see paragraph 6.2.5 a 5) and (b), A lower 90% confidence limit for this MTBF

Solution: (a) The total accumulated operating time on all 5 test items is 5x200 = 1000 hours = T. Thus, the point estimate of MTBF is $\hat{m}$ = 1000/5 = 200 hours. (b) To find the lower limit of the MTBF at 90% confidence, proceed as follows:

1) The number of degrees of freedom, ν is 2 (ν+1) =12
2) For a 90% confidence level, α = .10
3) In Table H-3b, page H-11, AMCP 702-3, under the column headed $\chi^2_{.10}$ for 12 degrees of freedom (ν = 12) find $\chi^2_{.10}$ = 18.549
4) Substituting in equation (1):

$$m = \frac{2T}{\chi^2_{\alpha;\nu}} = \frac{24x1000}{18.549} = 107.8$$

Thus, we have 90% confidence in the assertion that m = 107.8 hours.

Note that this value of 107.8 hours is considerably lower than the point estimate of 200 hours.

II. Failure Distribution Determination

a. Determine the failure distribution by the graphical means described in Appendix F, Section F-4, of AMCP 702-3.
b. If the failure distribution is found to be exponential, determine the lower 90% confidence limit as described under I above.
c. If the failure distribution is found to be normal, determine the 90% confidence limits as described in Appendix F, Section F-7, of AMCP 702-3.
d. If the failure distribution is found to be neither exponential or normal, refer the problem to a qualified reliability engineer for solution.

III. Probability of Mission Success

Calculate the probability of mission success for each type of test course for each of the four test course categories described in paragraph 6.3.3.3, as follows:

a. Determine the number of traverses, n. of each specified test course (single or multiple course traverse, as applicable) made by one test item. When several test items traverse the test course

simultaneously, n = number of test items x the number of traverses they make as a group, or the total number of trials.

b. Determine the number of traverses, r, of each specified test course which ends in a failure to meet the mission requirements described in paragraph 6.1.5. When several test items traverse the test course simultaneously, r = total number of failures encountered by all test items.

c. If $n \leq 30$, enter Table H-7 in AMCP 702-3 with the valued of n and r obtained as described above, to obtain the probability of mission success for the specific test course traversed.

Example: A vehicle makes 20 traverses over a specific single course. Eight traverses ended in failure to meet the mission requirements of paragraph 6.1.5. What is the probability of mission success in traversing this test course, at the lower 90% confidence level?

Solution: n = 20
r = 8

In Table H-7d; page H-21, AMCP 702-3 for n = 20, under the column headed 90%, find for r = 8, the value of .433. That is, we are 90% confident that the probability that the vehicle will meet the mission requirements is 0.433.

d. If $n > 30$, calculate the probability of mission success for the test course using the following equation:

$$P(\text{mission}) = \frac{1}{1 + \frac{r+1}{n-r} \quad F_{\alpha, \nu_x, \nu_y}} \qquad (2)$$

where P(mission) = probability of mission success.

α = the liklihood that the statement is incorrect. (This is 1-.90 = .10 when the confidence level is 90%).

$\nu_x = 2r+2$

$\nu_y = 2n-2r$

n and r are as defined under a and b above.

F_{α, ν_x, ν_y} may be found in Table H-5, in AMCP 702-3.

Example: A group of five vehicles is driven over a specified test course for a total of 50 traverses by the group. A total of two mission failures is obtained during this test. What is the probability that any one of these

vehicles will successfully meet this mission test, at a lower 90% confidence level?

Solution: n = 5 vehicles x 50 traverses = 250 trials.

r = two failures

$\alpha = .10$

$\nu_x = 2r+2 = 2 \times 2+2 = 6$

$\nu_y = 2n-2r = 2 \times 250-2 \times 2 = 500-4 = 496$

$F_{\alpha, \nu_x \nu_y} = F_{.10,6,496}$

In Table H-5a, page H-13, AMCP 702-3, for $F_{.10,6,496}$

find the value of 1.77

Substituting this value in equation (2):

$$P(\text{mission}) = \frac{1}{1 + \frac{2+1}{250-2} \times 1.77} = \frac{1}{1 + \frac{3}{248} \times 1.77}$$

$$= \frac{1}{1 + .0214} = \frac{1}{1.0214} \doteq .979$$

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)
U.S. Army Test & Evaluation Command
Aberdeen Proving Ground, Maryland 21005

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP
----

3. REPORT TITLE
U.S. Army Test and Evaluation Command Materiel Test Procedure
Common Tropic Environmental Test Procedure "Wheeled Tracked & General Purpose Vehicles"

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Final

5. AUTHOR(S) (First name, middle initial, last name)
----

6. REPORT DATE
22 January 1971

7a. TOTAL NO. OF PAGES
72

7b. NO. OF REFS
26

8a. CONTRACT OR GRANT NO.

b. PROJECT NO.
AMCR 310-6

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
MTP (2-4-003)

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
----

10. DISTRIBUTION STATEMENT

Approval for release, distribution unlimited.

11. SUPPLEMENTARY NOTES
----

12. SPONSORING MILITARY ACTIVITY
Headquarters
U.S. Army Test and Evaluation Command
Aberdeen Proving Ground, Maryland 21005

13. ABSTRACT

Procedures are described for evaluating the susceptibility of the subject equipment to the natural tropic environment. The environment is described in cause-effect relationships. Effects of weather, and microbiological growth are considered.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Vehicles						
Wheeled						
Tracked						
Environmental						